

Alpha Magnetic Spectrometer (AMS-02) Payload on ISS

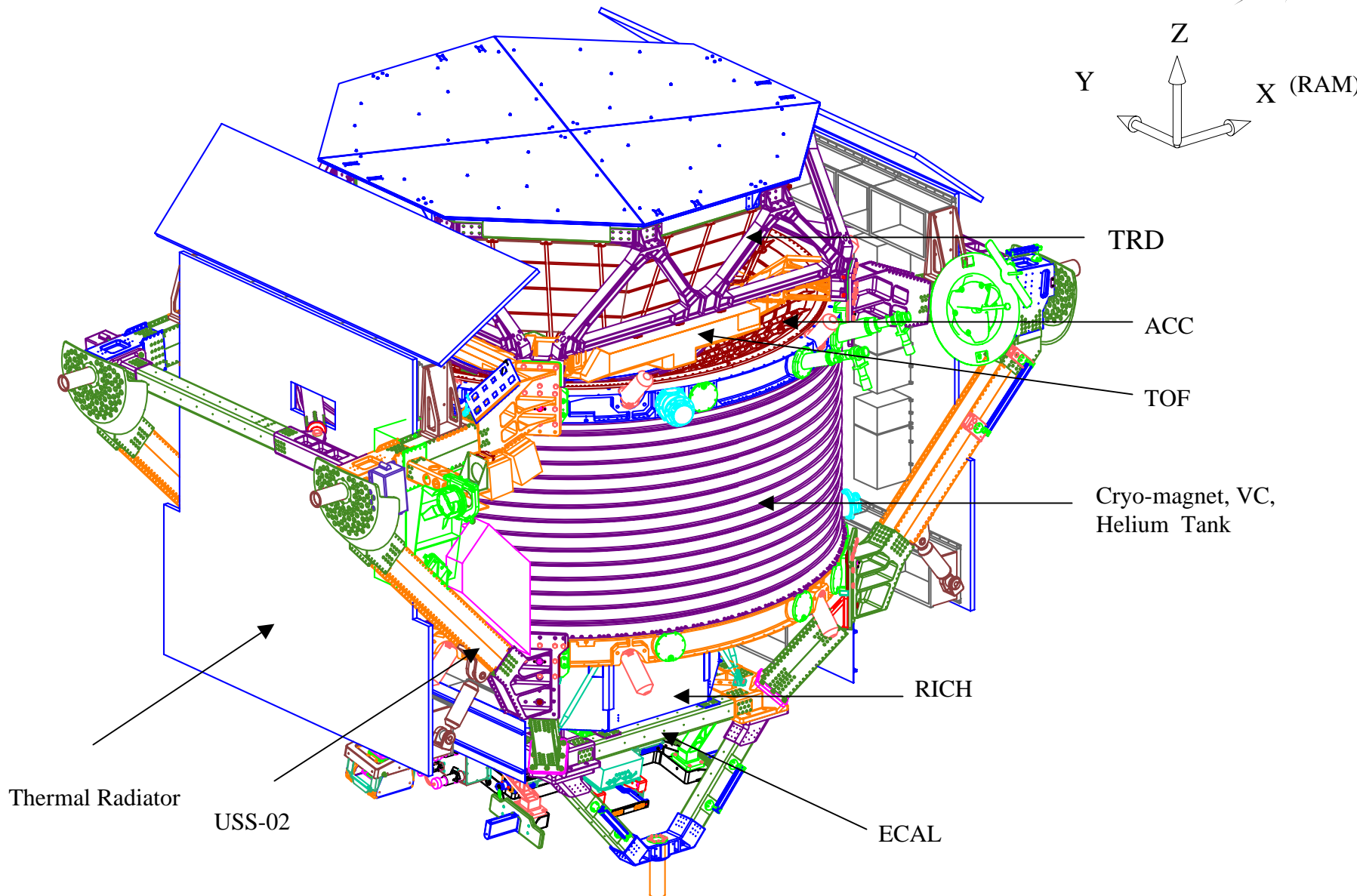
Critical Design Review of Materials and Processes

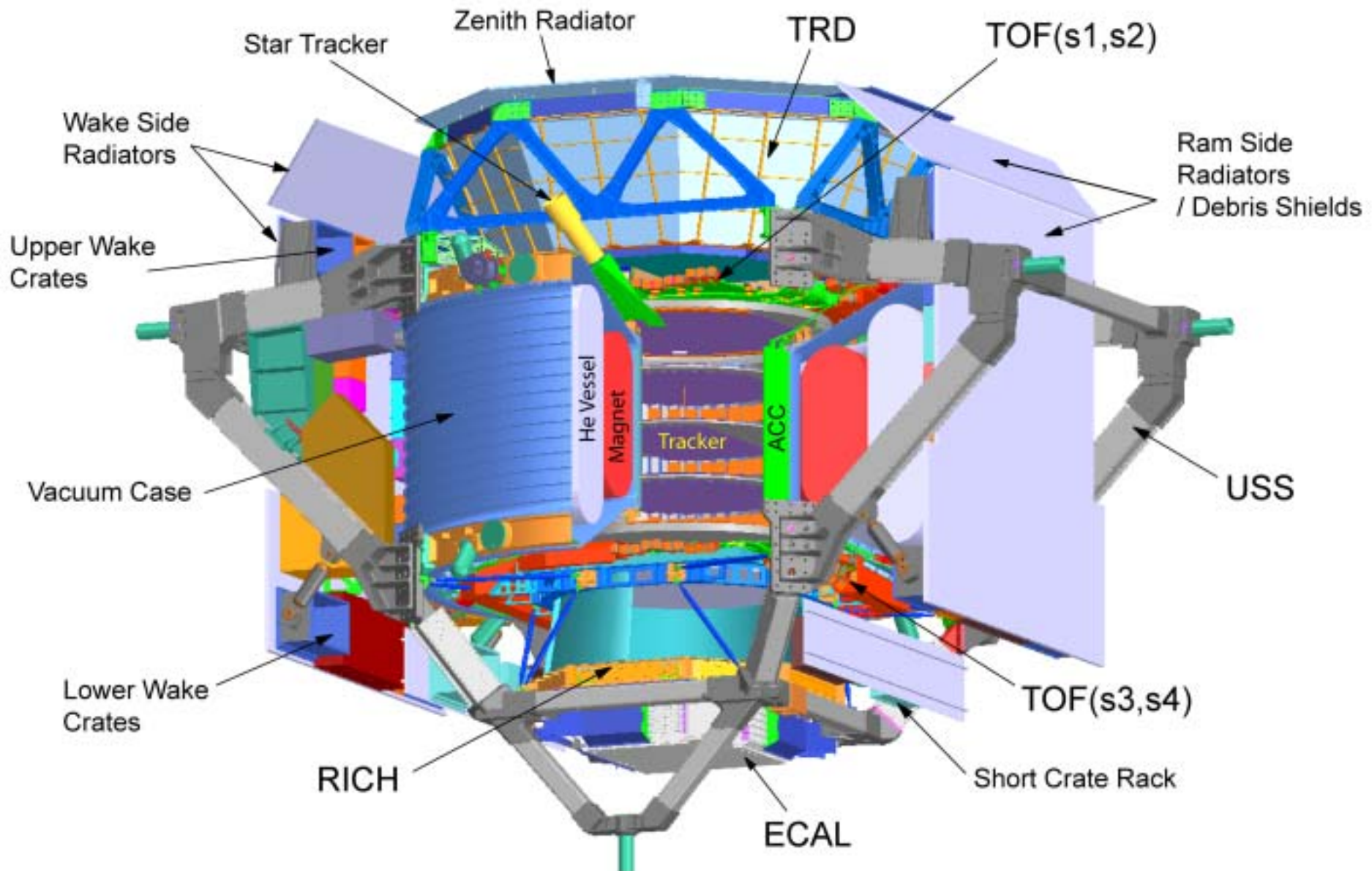
Rajib Dasgupta / LMSO-ES4 / 281-333-7043

John Figert / LMSO-ES4 / 281-483-8919

General Description of Payload

- AMS-02 is a follow-on flight for the AMS payload that was flown on STS-91. It is located on the upper inboard PAS#2 site of the S3 truss on ISS.
- AMS-02 will use a large cryogenic superconducting magnet and several high energy particle detector systems to study anti-matter, dark matter and cosmic rays.
- AMS-02 will be certified as an ISS attached payload for a period of 5 years.
- AMS-02 has the following major integration hardware and experiment systems
 - Unique Support Structure (USS-02)
 - Transition Radiation detector (TRD),
 - Anti-Coincidence Counter (ACC),
 - Tracker
 - Superconducting magnet
 - Time of Flight (TOF),
 - Electromagnetic Calorimeter
 - RICH

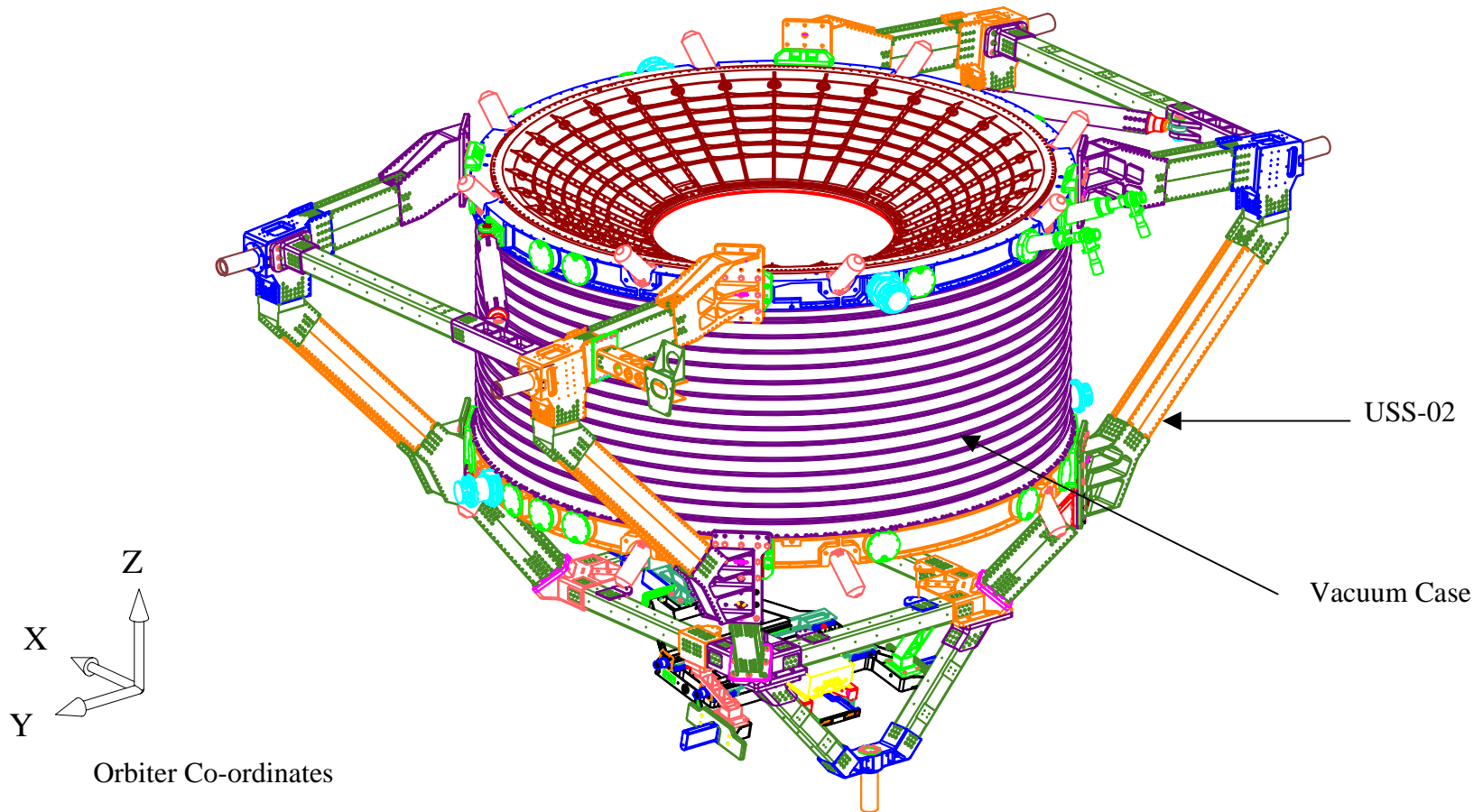




AMS-02 Materials Certification Requirements

- NSTS 1700.7B, ISS Addendum – Safety Policy and Requirements for ISS Payloads
- SSP 57003 – Attached Payload Interface Requirements Document.
- SSP 30233 Revision F – Space Station Requirements for Materials and Processes
- JSC 27301 D – Materials Control Plan for JSC Flight Hardware
- Mil.-Handbook. - 5H – Materials allowable for Design

Unique Support Structure (USS-02)





USS-02 Materials of Construction / Processes

- USS-02 is an assembly of primary and secondary structures that integrate the AMS-02 experiment hardware to the Shuttle payload bay and ISS structure
- List of materials is included in Appendix and in CDR data pack.
- Primary structure is 7050 T7451 Al. Alloy per BMS 7-323 specification. It is a high strength, fatigue tolerant, stress corrosion resistant Al. Alloy.
- Plates are machined into two c-channel sections. These sections are joined to form a closed section box beam by the Friction Stir Welding Process.
- Friction Stir Welding (FSW) is an established process used in the Shuttle External Tank construction. Details of the process are included in the Welding data pack (Point of Contact : Daniel Rybicki/LMSO)



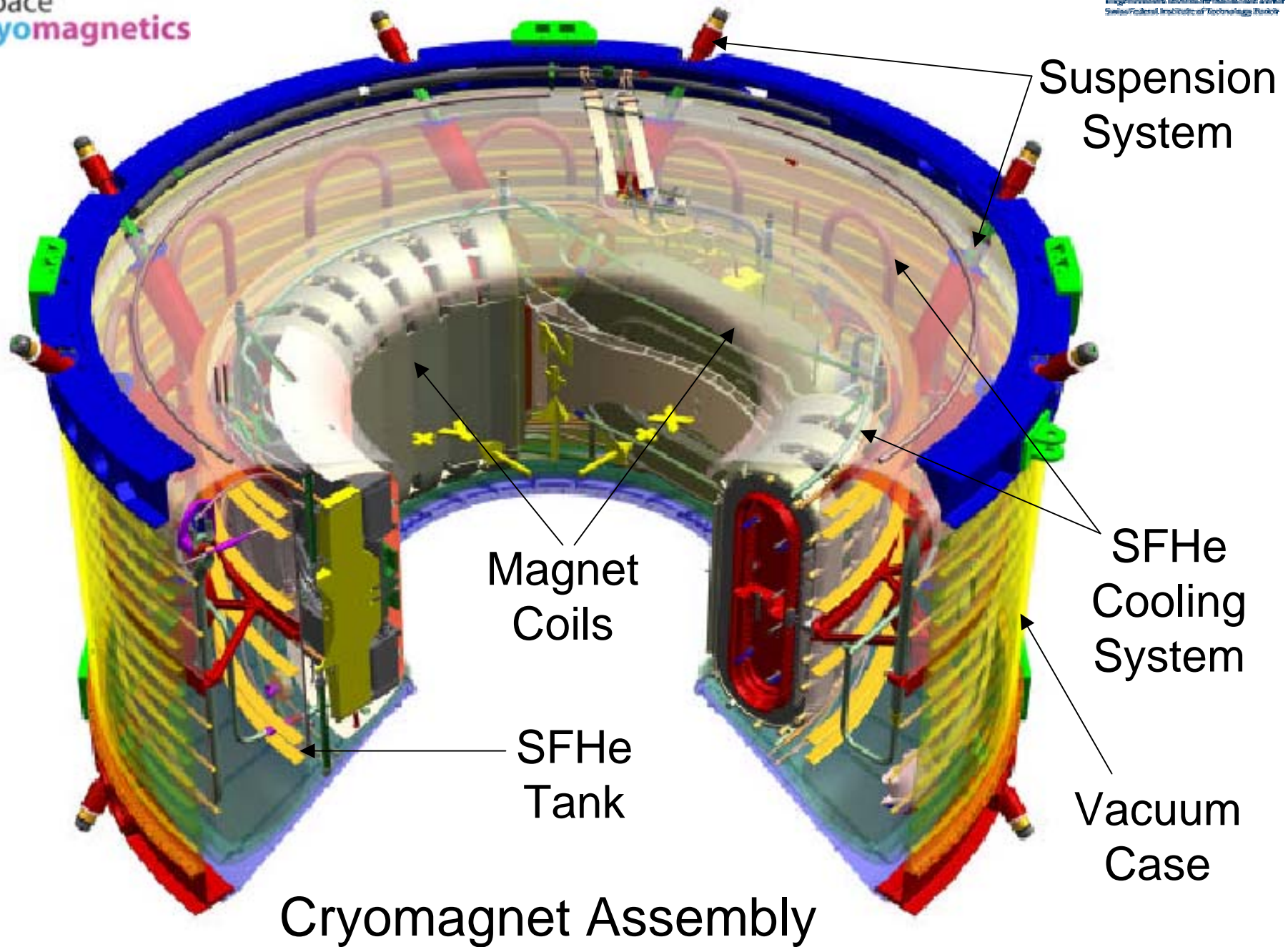
- Pre/Post weld heat treatment of 7050 alloy is required to improve stress corrosion resistance, tensile strength and ductility.
 - Pre-Weld Heat Treat : Solution Heat Treat at 890F for 1 hour and air cool per AMS-H-6088
 - Friction Stir Weld and Inspect per LMSO developed process for 7050 (PRC-0014)
 - Post-weld Heat Treatment : i) Solution heat treat at 890F for 10 minutes and water quench ii) Hold part for 96 hours at room temp. iii) Age harden to T74 condition by heat treatment at 250F for 5 hours and then at 325F for 27 hours.
- This unique heat treatment schedule developed by LMSO / John Figert. It results in minor or no development of large columnar grains. Hence, post heat treatment mechanical properties are excellent with high toughness and ductility.

USS-02 Materials of Construction / Processes

- Stress Corrosion Cracking Resistance of FSW 7050 specimens : Six (6) specimens were tested. Direct tension specimens according to ASTM G49. Two (2) specimens were stressed to 75% of yield strength (MSFC-STD-3029, Table 1 requirement) and four (4) specimens were stressed to 50% of yield strength (Table 2 requirement) in 5% salt spray environment for 20 days. No failure was observed. This is a conservative SCC evaluation approach and proves high SCC resistance of FSW 7050 material.
- Other materials of construction include 7075 T7351 for PAS components, Inconel 718 for trunnion, Al. Bronze bushings, 6061 T6511 tubes for diagonal strut, 7075 T73511 tubes for keel assembly.
- Self aligning and self lubricating rod end bearings (MIL-B-81935) WITH 15-5 PH body, 13-8 Mo balls and 17-4 PH stainless race.

USS-02 Materials of Construction / Processes

- Bolts, nuts and washers are CRESA286. Rivets are NAS1398 series Monel or Aluminum alloy. All structural fasteners have mechanical type positive locking features as secondary retention methods; ex: self locking bolts, locknuts, locking helicoils and key locked inserts.
- Thermal isolating shims are made of Titanium alloy or peelable stainless shim stock.



CryoMagnet Assembly –Materials of Construction

- Vacuum Case is a structural member that supports the superconducting cryomagnet by 16 composite straps. The magnet supports the superfluid helium tank by mechanical attachments (in the 3 primary directions). List of materials in data pack.
- Vacuum Case - 7050 T7451 ring forging for support rings, 2219 T62 spin formed plate for conical flange, 2219 T851 for inner cylinder and 7050 T7451 rolled ring forging for outer cylinder, Viton for O-Ring seal, 7050 T7451 for interface plate.
- Spin forming process qualification for Vacuum Case conical flange complete. L and LT samples tested from spin formed blank. Test data is acceptable.

CryoMagnet Assembly –Materials of Construction

- Helium Tank - 5083 H321 plate and 5083 H111 forging. Test data for AA5083 forging samples (weld and base material) at 7K well exceeds specification values.
- Cryomagnet assembly - 6061 T651 (10” thick) plate for primary structural components, 2219 T 87 for various structural components, 316 LN for strap clevis, Fiberglass/epoxy and carbon fiber/epoxy straps for magnet support.
- Cryomagnet assembly - 6061 T651 (10”) plate tested and material allowable established with NASA-ES4 concurrence. All other materials are certified to AMS or British Specification. Composite straps being certified by structural testing per Structural Verification Plan.

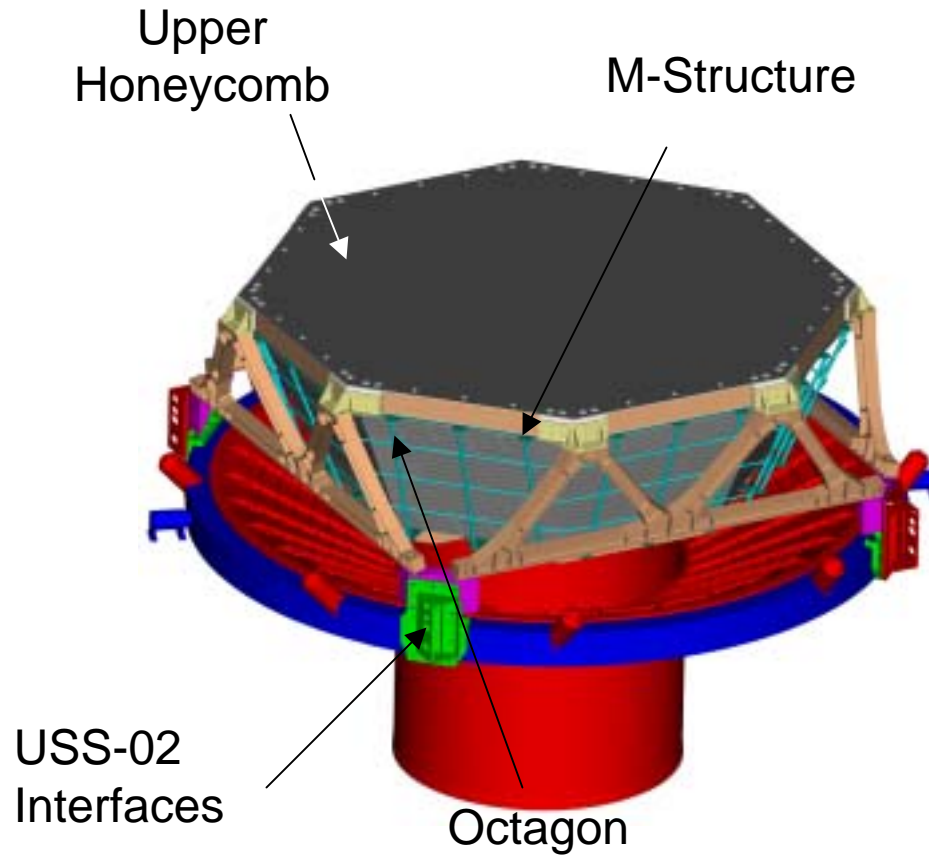
Corrosion Control Plan for AMS-02 integration hardware

- All Al. Alloy piece parts to be anodized per MIL-A-8625, Type 2 Class 1 or Class 2 Dyed (Per Federal Standard 595).
- Aluminum alloy components that need electrical grounding shall be Nickel plated per PRC 5004 and PRC 5007.
- Insert holes, rivet holes, counter bored holes and straight through bolt holes shall be Chemical Conversion coated (MIL-C-5541). Inserts shall be wet installed using Super Koropon 515-700 / 910-740 or Aeroglaze 9743 primer.
- Aluminum Bronze Bushings have severe galvanic corrosion problems with Aluminum structure interface. All Aluminum Bronze parts shall be wet installed with primer as noted above.

Corrosion Control Plan for AMS-02 integration hardware

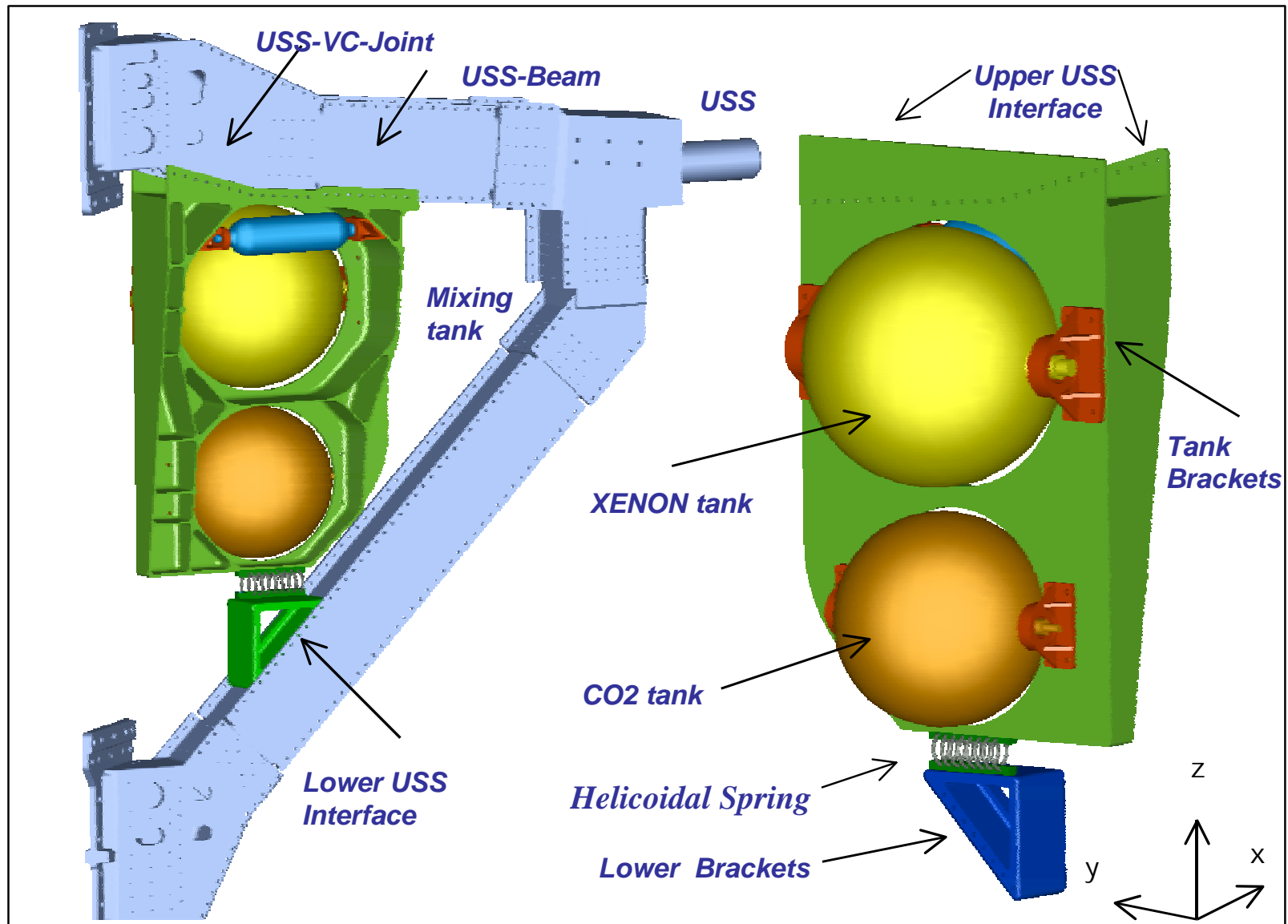
- All Stainless parts shall be cleaned and passivated per AMS - QQ-P-35. Shear pins made of Custom 455 shall be installed with primer as noted above.
- The internal surfaces of the inner and outer cylinder of the vacuum case will be masked during anodizing. These surfaces will be subsequently coated with “Irridite” Chemical Conversion coating per MIL-C-5541 Class 1A.
- Sealing surfaces of the vacuum case shall be coated with High Vacuum corrosion protection grease from Dow Corning.

Transition Radiation Detector (TRD)



RWTH
Physics *AC-1*

TRD Gas Supply System



TRD / ACC

- TRD - composed of several layers of detectors that contain Xe/CO₂ gas. Detectors contained inside a composite Octagon secondary structure. Octagon supported by an Al. Alloy M-structure. Detailed materials list available in data pack.
- Structural materials are AA 7075 T7351 for M-structure, Ti6Al4V for brackets, M40J Carbon / L285 epoxy for Octagon. Non-structural materials are Separet 405 non-woven fiber for the radiators, Stycast 1266, Hysol EA934NA etc. for adhesive non-structural bonding.
- Composite structures are qualified by static load of each panel and a side panel corner junction test per AMS-02 structural verification plan.

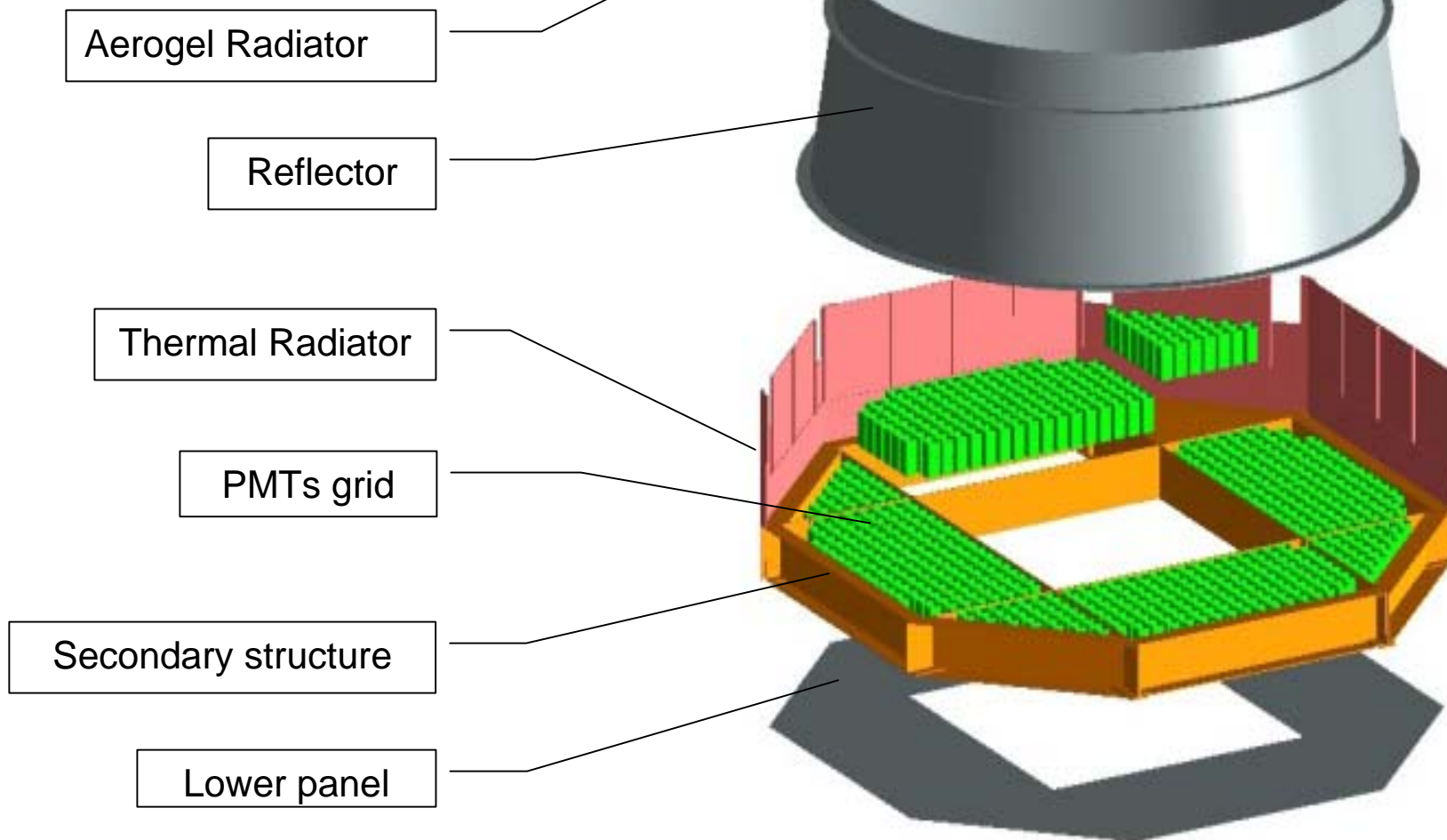
TRD / ACC

- TRD Gas System – AA 7050 T7451 for support structure, CRES A286 bolts, Composite Overwrap pressure vessel (ARDE), CRES 316 for piping and manifolds, AA6061 T6 for valve bodies and valve mounting
- ACC – Carbon Fiber Composite (Tenax fiber / Araldite LY556 resin) for support tube, AA7075 T7351 for photomultiplier support, Black Polyester fabric for light tight blanket over ACC Modules, Bicron BC600 and CV 1146 adhesive sealants. The ACC support tube and fibers are identical to AMS-01.



Carlo Gavazzi Space SpA

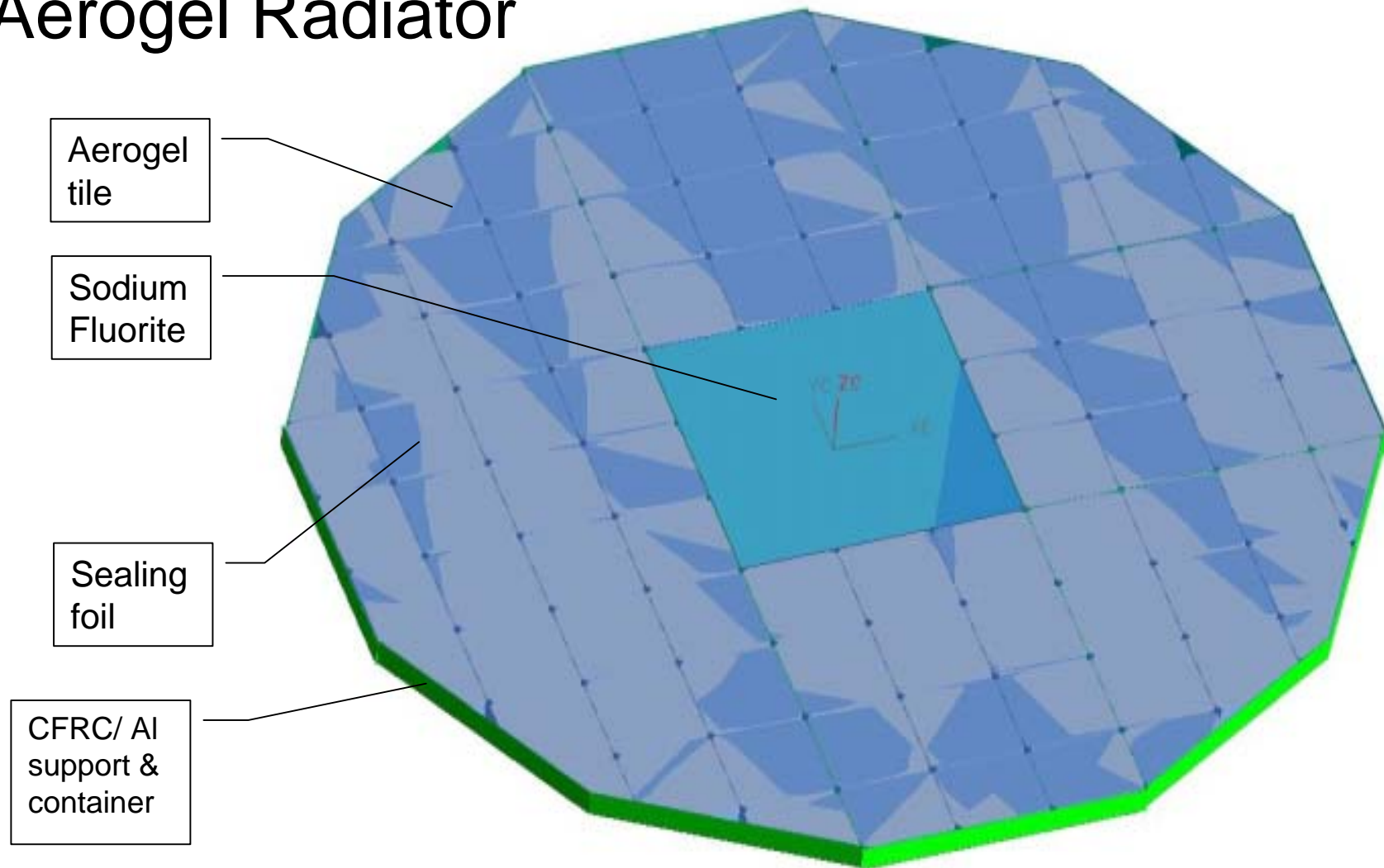
RICH assembly





Carlo Gavazzi Space SpA

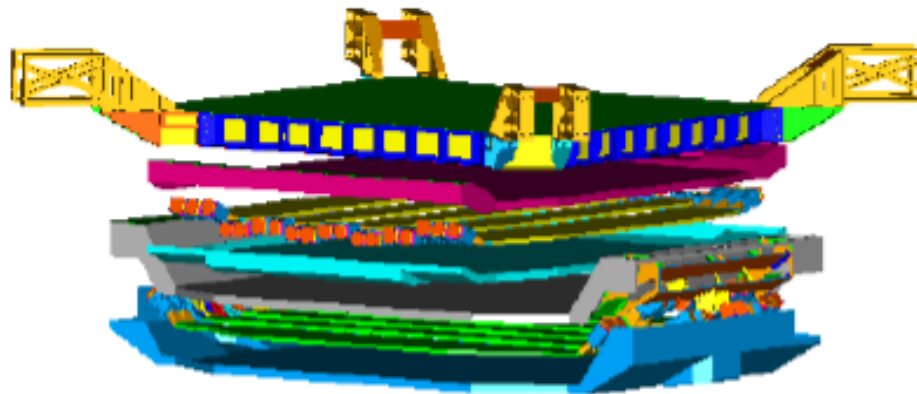
Aerogel Radiator



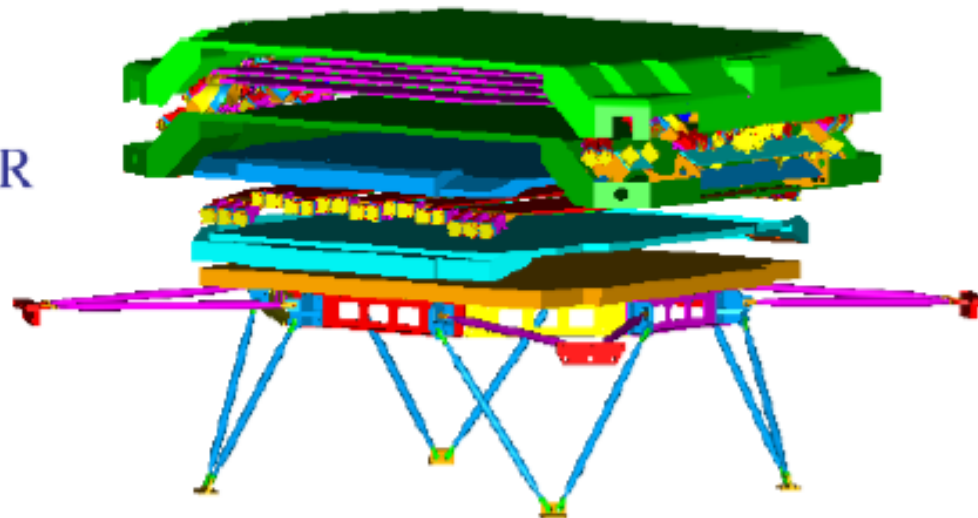
AMS II

ToF

UPPER



LOWER

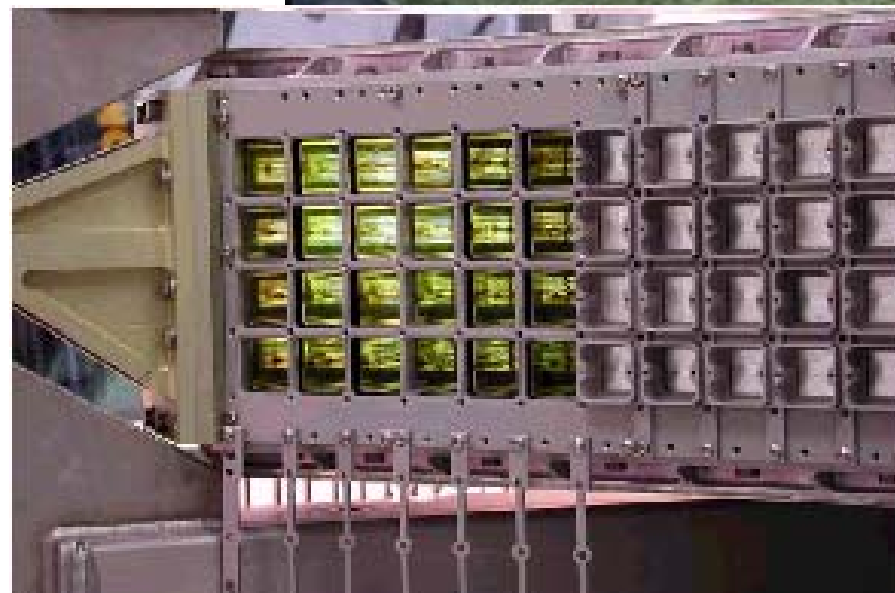


RICH / TOF / Tracker

- **RICH** – Two (2) major components; Photo-multiplier tubes and the Reflector. Major structural materials are AA7075 T7351, 6061 T651, CRES A286, 304 and 316 , 15-5 PH H1025 etc. Major non-structural materials are EX1515 cyanate ester / graphite lay-up for reflectors, Vacoflux 50 Co-Fe alloy and ARMCO soft iron for PMT shielding., Silica Aerogel and Sodium Fluorite (completely encapsulated with 1 mm Plexiglas sheet), CV1152 silicone, AV138 and 2216 epoxy adhesives.
- **RICH** Materials Identification and Usage List (MIUL) submitted by Carlo Gavazzi. MIUL has been reviewed and found acceptable.
- **TOF** – Scintillation counters supported on Aluminum Honeycomb panels. Honeycomb panels made of AA 2024 with AA 5052 core., AA 7075 for structural brackets and extension beams, AA 6061 T6 for thermal radiators. Non-structural materials are Plexiglass for light guides, Araldite AV138, CV1146 and CV1152 for sealants and conformal coating, DC93-500 silicone compound for potting etc.

RICH / TOF / Tracker

- TOF Materials list has been reviewed. Materials Usage Agreement (MUA) shall be written to justify Stress Corrosion Resistance (SCC) deviation of AA 2024, used in Honeycomb skin. No issues identified, as part is non-fracture – critical and experiences low sustained tensile stresses
- Tracker – AA 7075 T7351 for tracker ladder legs, AA 5056 for outer plane honeycomb core, cytec fiberite HYE 3454-3J (M55) carbon fiber/cyanate ester resin for Tracker structure outer plane, Airex foam (enclosed inside upilex film), Epotek H20E and H70E adhesives for front end electronics, RTV 695 for conformal coating.





Electromagnetic Calorimeter (ECAL) Materials of Construction

- Active part consists of stack of lead foils and scintillating fibers. The active part or “superlayers” are enclosed inside the Al. Alloy box structure. Box is made of top and bottom honeycomb plates bolted to 4 lateral panels.
- Major structural materials are AA 2014 T6 for I-beam of Honeycomb structure and side panels, 2024 T4 for Honeycomb structure faceplate and 7050 T7451 for Brackets and Supports. Brackets and Supports are fracture critical parts.
- Non-structural materials are Therm-A-Gap A274 and T274 silicone elastomers, DC93-500 potting compound, PMMA light guides, Polycarbonate for PMT support etc.
- Structural and non-structural materials list has been reviewed. Materials Usage Agreement (MUA) shall be written to justify use of AA 2014 and AA 2024. Usage of these materials have been discussed with NASA-ES4 experts (Glenn Ecord) and no issues identified. All fracture critical parts are made of Stress Corrosion Resistant AA 7050 T7451.
5/18/2004



Electronic Crates and Avionics Materials

- Electronic Crates are hard mounted at various locations of the Unique Support Structure and contain the AMS-02 electronics.
- Electronic Crates - AA 7075 T7351 and AA6061 T6 for mechanical parts. All crate Al. alloy parts are anodized for corrosion protection. Fasteners are made of CRES 300 series. NASM 21209 self locking helicoils are used. Other materials include Eccobond 285 and Scotchweld 2216 epoxy adhesives, Chotherm 1671 Silicone gap filler, Solithane 113 for conformal coating of PCB's and ETFE (Tefzel) insulated cables.
- Avionics Components for Integration hardware – PTFE insulated wires and cables (M22759/12, M27500XXX06), Teflon insulated fiber-optic cables (NFOCXXX), Nickel plated Connectors (40M, SSQ21635 and MIL-C-38999 series), Solithane 113 conformal coating for external applications, DC3140 for aft flight deck applications, Permacel P213 glass cloth tape etc. All exposed PTFE wires will be wrapped with glass cloth tape.
- Materials Identification and Usage list (MIUL) for Crates has been submitted by CGS and reviewed. All of the materials and processes are acceptable.

Materials Assessment

Stress Corrosion Cracking

All structural metals have been reviewed. Majority of the materials are “A” rated for stress corrosion cracking resistance per MSFC-STD-3029. SCC assessment of major structural materials are as follows:

- 2014 T6 and 2024 T4 use in ECAL structural components – MUA will be written and approved by NASA-JSC-ES4. Primary rationale are a) Lack of sustained tensile stresses b) None of the components are Fracture critical or single point failure c) Materials have been successfully used in the Chinese Aerospace industry without any SCC related failure. Application has been discussed with NASA/Glenn Ecord. No issues identified.
- Use of 2024 plate in TOF Honeycomb skin – MUA will be written and approved by NASA-JSC-ES4. Primary acceptance rationale are a) Material has SCC threshold stress of 30 Ksi in ST b) Component is secondary structure, non-fracture critical and is subject to low applied tensile stresses.

Materials Assessment

Stress Corrosion Cracking

- 7050 T7451 in different structural components – This alloy is rated “U” (undetermined) in the NASA materials database. However, material has high SCC resistance per BMS 7-323 specification. Proven use in various ISS structural components.
- Friction Stir Welded Samples of 7050 T7451 have been successfully tested for SCC resistance per Table 1 (A rated or 75% of yield strength) requirements of MSFC-STD-3029. Test results indicate no failure. No Materials Usage Agreement (MUA) is required.

Materials Assessment

Material Allowable verification

- Allowable for structural materials have been taken from MIL-HNDBK-5 wherever available.
- Material procurement specifications (ex: AMS, ASTM, British Specification etc.) have also been used for material allowable.
- Extensive testing conducted to establish allowable for materials which are out of specification (ex: 6061 T651 10" plate). Allowable based on test data concurred by NASA/ES4 Metallurgist.
- Certificate of Conformance (C of C) shall be verified against material specification to ensure quality control

Materials Assessment

Fastener Certification

- Fastener Integrity verification is done per JSC 23642 C, “JSC Fastener Integrity Testing Program” .
- All structural fasteners have positive back-off prevention such as mechanical locking features like Helicoils, key-locked inserts, Locknuts, safety wires or fused locking elements. Deviations to this will be noted in the Materials certification and adequate rationale provided.
- Structural fasteners (Fail safe and Safe Life) ,#8 and larger are lot tested per lot/sample size of JSC 23642.
- Structural fasteners will be certified by verifying Certificate of Compliance and Material Test Report (MTR). For Fracture Critical fasteners, procurement of mixed batches of fasteners are not allowed.

Materials Assessment

Corrosion control

- Integration hardware and all structural components designed to meet guidelines of the Lockheed Martin Corrosion Control Plan (earlier slide). This plan meets class I requirements of MSFC–SPEC–250 for corrosion protection finishes and galvanic corrosion protection.

Flammability

- All exposed materials are “A” rated for flammability in the Payload Bay environment per requirements of NSTS 1700.7B. Flammability configuration analysis per guidelines of NSTS 22648 indicates payload meets flammability configuration requirements for Spacecraft applications.

Toxicity

- AMS-02 is ISS external attached payload. It does not have any components that interface with the ISS internal habitable environment. Hence, Toxicity requirements of NSTS 1700.7B are not applicable.

Toxicity (Contd.)

- AMS crew operations post (ACOP) is located inside the IVA pressurized volume and will be certified to NSTS 1700.7B Toxicity requirements.

Atomic Oxygen (AO)/Vacuum Ultra-Violet (VUV) Resistance

- All exposed materials have resistance to AO/VUV degradation or protected from AO fluence by AO/VUV resistant thermal blankets.
- Major exposed non-metallic materials are CFC Octagon structure (TRD), CFC mirror assembly (RICH), some electrical power cables, black polyester wrapping material for ACC module, CFC tubes for Tracker radiator support and TOF structural boxes.
- Thermal Blankets will cover all of the major exposed non-metallic components.
- All exposed integration electrical cables will be wrapped with Permacel P213 Glass tape.
- Silver plated fasteners are not used in line of sight of Atomic Oxygen.

Materials Assessment

Thermal Vacuum Stability (External Contamination)

- Pre-CDR list of non-metallic materials and outgassing analysis presented to ISS external contamination team. No major issues identified.
- Major exposed materials have been tested per ASTM E1559 spec. for long duration outgassing data.
- All other materials have “A” rating per ASTM E595 / SSP30233F requirements.
- Data presented in attached matrix.

Thermal Vacuum Stability (External Contamination)

- Materials tested per ASTM E 1559 have outgassing rates of the order of $10\text{E-}14$ gms /cm²/sec at 25C TQCM collector. Corresponding rates for –40C TQCM is in order of $10\text{E-}12$ gms /cm²/sec.

Thermal Vacuum Stability / Outgassing data

Material	Manufacturer	1559 Test Data	595 Test Data
Hysol EA 934 na	Dexter Corporation	N.A.	TML-0.5% VCM – 0.00%
Hysol EE 4215 / HD 3561	Dexter Corporation	N.A.	N.A.
Araldite AV 138 / HV998	Ciba Polymers	N.A.	TML-0.6 to 1.0 % VCM – 0.05%
Bottom/Top Honey comb Plate (EpoxyEP121 – Graphite FabricC15HTA5131) with EC 622 Void Filler	Eurocomposites / Hexcell	To be Tested	Outgassing Rate Tested Configuration Thermal Vacuum Stability Test Performed.. Average Condensation Rate less than 5.4 x 10E-12 gm/cm2/sec.
Octagon Panels Honeycomb-M40J Carbon Fiber with L285 Epoxy Resin and Al. 5056 Core	Toray, M.G. Scheufler, Hexcell	Test Conducted. Outgassing Rate after 144 hours 50C-233K is 1.32 x 10E-12 gms/cm2/sec after 144 hours.	N.A.
Separet 405 TRD Radiator Felt Non-woven fabric	Aachen, Germany	Tested at 30C-248K. Rates were 4x10E-14 gm/cm2/sec.after 144 hours	N.A.
Araldite AV 138	Ciba Giegy, Europe	~1x10E-12	N.A.

Thermal Vacuum Stability / Outgassing data

LOCKHEED MARTIN



Material	Manufacturer	1559 Test Data	595 Test Data
Columbus "Optimal" Black Cloth – Polyester Fabric	Aachen	3x10 E-12 gms / cm ² / sec for 40C-233K after 144 hours.	N.A.
Upilex Film. Identical to Kapton Film	Cicorel, CH	N.A. This material is not planned to be tested	VCM for Kapton Film is; TLM-0.1%; VCM-0.03%. Kapton Film low outgassing.
Epo-Tek H20E	Epoxy Technology	N.A.	TML-1.0% VCM-0.01% to 0.06%
BC 600 Optical			
CV 1146 Black Silicone	Nusil Technology	N.A.	TML-0.5% VCM – 0.05%
Graphite Fiber impregnated with Cyanate Ester Resin (M55J impregnated with EX-1515)	Bryte Technologies Incorporated	No Test needed.	TML-0.24 %, VCM-0.04%
Solithane 113 Conformal Coating	Uniroyal Chemical	N.A.	TML – 0.74% VCM – 0.08%
DC93-500 5/18/2004	Dow Corning	N.A.	TML-0.74% VCM – 0.07%

Conclusions

- Drawings / Materials lists and Processes have been reviewed for all integration hardware, experiment systems, avionics hardware and found acceptable.
- Current Design of Thermal Control System hardware (Radiator and Thermal Blankets) has been reviewed. Final assessment of this design is future work.
- Materials assessment for AMS crew operations post (ACOP), located in the IVA environment is future work.
- AMS-02 Payload is acceptable for Materials and Processes at CDR stage.